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Carnegie-Mellon University
Software Engineering Institute

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Peter Capell

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Peter Capell

Community Sector

Software Engineering Institute
Carnegie Mellon University
Pittsburgh, Pennsylvania 15213

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SEI Joint Program Office
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5 Eglin Street
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This report has been reviewed and is approved for publication.

FOR THE COMMANDER

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Abstract: This report provides a wide view of the costs, risks, and benefits associated with instructional technology alternatives. The number and variety of possible paths to learning through this technology have increased markedly in recent years with the advent of interactive multimedia, satellite communications, and the Internet. More than ever before, learning technologies have created new educational possibilities for people and organizations. In this era of increasing financial stringency, we are obligated to examine these new possibilities in light of their obvious advantages: replication of high-quality instruction, lower overall costs, increased quality in educational outcomes, and the ability to provide these benefits over long distances. This report will show that with today's computer-based instructional technology, the question is no longer *whether* to use the technology, but rather *how* to use it.

1 Overview

This report provides a technology-independent rationale for an overall distance-learning strategy, including a compilation of the author's and reviewers' views on distance-learning approaches.

Following an introduction, overview, statement of the objectives of the report, and a presentation of the assumptions guiding the report, Section 1.3, Current Status, describes the current educational and technological decision space that this document addresses. Section 2, A High-Level Look at Core Educational Issues, is a discussion of features that affect learning. My intention in writing this chapter is to provide the reader with a description of certain educational premises used in making determinations about the relative effectiveness of learning systems. Section 3, Computer-Based Multimedia and Related Solutions, summarizes the characteristics of the set of educational technologies described in this report. A large part of this section deals with multimedia and related solutions, because multimedia represents extremes on two fronts: tremendous positive potential for distance learning and high development cost. Additionally, multimedia and related solutions include a superset of the issues for all of the computer-based learning systems that could possibly be deployed. Section 4, A Technology-Specific Analysis, is a detailed review of these technologies relative to their associated management complexity, cost, and learning-effectiveness values. Section 5, Summary, Recommendations, and Conclusions, suggests possible deployment scenarios. Because the list could be voluminous, only a few examples are given as realistic candidates. Appendix A provides one example of the needs of a course devleopment process.

1.1 Objective of the Report

The purpose of this report is to provide sufficient background knowledge of delivery systems to enable sound decisions to be made about the deployment of courses focusing on three lev-

els of student proficiency. I present the systems in this report in consideration of their ease of implementation, cost, educational benefit, and ease-of-fit to today's practices.

1.2 Assumptions

Alongside cost and risk, I will feature educational concerns prominently among the issues that determine the type of delivery solution recommended. Assumptions about the organizations to which this report is addressed are

- A certain amount of instructional infrastructure is already in place.
  - Satellite hardware and system support is readily available for wide-scale transmission of one-way and potentially two-way educational offerings.
  - The existing computer hardware base is composed largely of Intel® microprocessor-based machines, capable of delivering text-based instruction [computer-based training (CBT)].
- The organization is willing to explore the possibility of expanding the existing infrastructure to include technologies capable of interactive multimedia[1] and other advanced computer-based instructional solutions.

1.3 Current Status

Given today's austere budgets and the likelihood of future budget reductions, organizations need to plan for this trend for the foreseeable future. At, say, $1400 for travel and per diem for each student, the cost of training can become prohibitively expensive. Travel and per diem alone often account for more than half of the cost of a course. For many organizations, reducing these travel and per diem figures has become imperative.

1. *Multimedia* is defined here as digital audio, video, images, music, text, or animation that is integrated on a computer system.

2 A High-Level Look at Core Educational Issues

There are many possible strategies for distance learning delivery that could support or potentially replace the current state of educational practice. The main issues are educational benefits and costs. The costs of implementing any instructional system, whether computer based or human, are high. There will always be a cost for developing a system, maintaining it, transitioning it to others who will teach it, distributing it, and so on. In this part of the report, I discuss costs and educational benefits in sufficient detail to enable a sound choice to be made among possible system implementations.

2.1 General Learning Factors

The best educational practices must be folded into any distance-learning strategy. While there are many other learning factors, the scope of this report will be limited to an essential few.

2.1.1 Interactivity

Interactivity is a set of measurable instructional qualities such as "time on task," "immediacy of feedback," "learner engagement," and so on. Laurel [Laurel 86] provides the following definition:

> *Interactive frequency, range, and significance correspond to how often user input is enabled, the range of choices available to users at a given moment in the interaction, and the impact of the user's choices and actions on the whole experience.*

In the world of educational technology, interactivity has become a byword for high quality in learning materials. Even though this term is still gaining clearer definition and is sometimes carelessly applied, it is useful in describing a general characteristic important to any effective instructional system—that the learner must be continuously and actively engaged.

2.1.2 Learner Adaptability

Another area of prime instructional concern is the adaptability of the learning system to the individual student. In human terms, this adaptability comes in the form of a tutor. Human tutoring is considered by educational researchers to be among the most effective forms of instruction [Anderson 85]. One reason for this is the tutor's ability to home in on students' misconceptions and provide problems and explanations appropriate to individual needs in real time.

Computer systems that emulate the methods of human tutors are called *intelligent tutoring systems*. These systems are capable of providing all of the interactive features of multimedia in addition to precise commentary on the student's performance and the selection of remediations that are appropriate to an individual student's needs.

2.1.3 Situated Learning

It is well known that learning is enhanced when it takes place in a context that is much like that in which the student will be expected to perform after instruction.[2] While this may seem obvious to most of us, the idea of situated learning has not traditionally been used in most classroom instruction. The most readily available example of a situated learning experience is a simulation. Flight simulators, for example, are designed to provide the trainee with as close an approximation of actual flight as possible. In theory, with enough refinements, it would be possible to create an instructional system that would permit the immediate assignment of pilots to aircraft upon completion of instruction. While actual flight training always includes time in a real aircraft, it is technologically feasible to avoid this step entirely.

In terms of regular classroom circumstances, however, situated approaches call for ways of mimicking the circumstance in which the students will be expected to use their knowledge. This mimicking can involve role plays or any other teaching device that will reconstruct an experience similar to "real life." Moot court, simulation, and role play are all common teaching methods for situating the learning experience.

2.1.4 Retention

Retention of information is the ability to recall it on demand after instruction. Anything learned decays in the time between the training and application. Recently, technology has opened another door to the possibility of providing these features in the form of on-the-job electronic performance support. Electronic performance support systems (EPSS)[3] provide in-context instruction as a job is being performed (see Section 3.5.1). The more practice a student has in a realistic setting, the more likely the knowledge is to "stick." An optimal instructional system would provide highly interactive, realistic (situated) training, preferably in a time frame very close to its actual use in a job or on a project. Further, the optimal training system would be readily accessible, so that any forgotten information or skill training could be revisited on demand.

2.2 The Importance of Bloom's Levels

Bloom's taxonomy [Bloom 56] provides a means of targeting course expectations to potential audiences (GS levels). In this section, I address Bloom's levels in the context of the technologies described in this report.

There are two primary assertions that provide useful guidance in applying Bloom in the technological context:

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2. Beginning with the work of David Ausubel in the mid-1970s, educational researchers began to examine the concept of *grounded theory*, the notion that it is important to consider the instructional context as a factor in learning.

3. For a complete military case history on EPSS, see DTIC Document No. AD-A201 401, *Implementing Embedded Training (ET)* [DTIC 88].

1. Computer-based multimedia can be employed for any of the six Bloom's levels of learning.
2. By properly specifying the objectives for a course using Mager's model [Mager 62] for performance objectives and Bloom's levels, reasonably accurate projections about the scope, scheduling, and cost for a multimedia project can be determined.

The second assertion above is essential from a project-management standpoint, because the complexity of the performance objectives will have implications for the technical development of the system. For every interaction specified in the curriculum, there will be a corresponding set of system requirements implied. The first hints at the overall complexity and scope of a computer-based multimedia system will be seen through its objectives, and, depending on Bloom's levels, will imply more or less complexity. For example, after creating a series of training objectives for Bloom's level 4 through 6, based on their descriptions, system designers can ascertain some of the complexity of interactions suggested: how much programming will be needed, what kinds of photos and renderings may be required, whether video will be needed, and so on. This level analysis is still "gut feel;" however, combined with critical path analysis techniques, this kind of estimate is much more meaningful than guesswork alone.

2.3 Consistency of Training

Consistency of training means that once the developer has managed to create a successful training system, there is no degradation from one class to another in terms of instructional quality. The reason for a tight specification of the instructional system is to ensure consistency and high quality in a curriculum used by many instructors. When the objectives are spelled out, the quality of instruction can be measured in terms of the objectives. Even with tight specification, there is often much inconsistency between any two human instructors. One of the positive features of a well-designed, interactive, computer-based training system is consistency of training throughout the life of the subject matter.

2.4 Costs: Time and Money

With technology-based solutions, costs always depend on the complexity of the solution. For example, while a satellite-based course need not require any more time in design and materials than a regular on-site course, it will incur cost for the uplink and added complexity for mailing of materials and remote monitoring of test results. Although these processes can be made efficient, costs related to satellite course delivery will be relatively permanent. With multimedia, there are large costs for planning and development. Lead times are often long (greater than eight months to delivery), and supervision of the development effort is a required and time-consuming activity. With traditional human-based instruction, development and delivery costs are high, especially with necessary travel included.

3 Computer-Based Multimedia and Related Solutions

The following paragraphs describe available technologies that are candidates as distance-learning solutions. I will present a high-level view of instructional technologies as background for a more detailed comparison of each technology against specific criteria related to development and learning factors.

The word *multimedia* has come to include many possible educational delivery strategies. In this document, multimedia is the integration of digital video, audio, text, graphics, or sound (in any combination) in a computer system. Virtually all computer-based training and educational delivery solutions could have multimedia elements associated with them. In the most elementary computer-based training (CBT) systems, the level of interactivity between the user and computer typically consists of a set of fixed responses. A reasonable system response is "Sorry, try again," at which point the student is routed back through a presentation of the initial course materials in the hope that learning will happen on a second or third explanation of the same concept. Even in the worst case, with only text and the limitation of fixed responses, this basic model of instruction has proven to be effective. With the addition of interactive videodisc and graphics, systems of this kind advanced in their variety and diversity, and the term multimedia began to gain prominence.

The following list includes broad categories of the computer-based delivery systems currently available in which some level of multimedia is likely to be a part:

- Hypermedia and Internet-based instruction
- Just-in-time lecture
- Intelligent tutoring
- Commercial off-the-shelf (COTS) training

Multimedia has stepped beyond simple text-based responses such as "sorry, try again," not by changing the complexity of the underlying computer program, but by adding color and variety to the user's environment. Thanks to significant and timely technological improvements, we now have a wide assortment of media techniques that can be applied to make the learning environment more interesting and dynamic. In truth, there is nothing inherently new about the modes of delivery in the multimedia-based learning technologies. In one form or another, classroom teachers have been using multimedia since the 1950s. Film, overhead projectors, chalkboards and tape recorders are all forms of multimedia that teachers have used to provide a richer classroom experience for their students. All of these media strategies now have their corollaries in the current multimedia gold rush.

What *is* new with computer-based multimedia is the integration and automation of these features in a tightly focused way, assuring repeatability of instruction. Approximately 10 years ago, there were many start-up efforts by researchers in the area of videodisc-based multimedia, beginning with such projects as MIT's Aspen Project, a system that provided an interactive video tour of Aspen Colorado. And there were the new Discovision™ systems with "level two"

interactivity, and the "Puzzle of the Tacoma Narrows Bridge Collapse," which provided learners with a new and interesting window into the physics of standing waves.

One important attribute that has changed since that time is the digitizing of media (particularly video) so that we no longer need to use the large-platter videodisc to capture analog video. The change to all-digital media now permits the use of full-motion video, animation, and audio on networks. It is possible to have independent usage of a training program by as many as 40 users on a single local-area network (LAN) with complete multimedia functionality. This means that entire courses can be made available anywhere on the earth with appropriate computer hardware, including the ability to monitor student progress remotely on a remote mainframe through Internet or other long-distance network.

Additionally, the tools to produce highly interactive systems have improved continuously, resulting in more and better system and learner interactivity in the training programs that are being developed. Today, there is really no question of the instructional efficacy of interactive technologies. Regardless of subject matter, sophistication of audience, or complexity of training mission, the means now exist to create a computer-based educational solution fully competitive with any traditional classroom, and in some instances competitive with the ultimate instructional system, the human tutor.

The following paragraph is an abstract taken from the Institute for Defense Analyses (IDA) [Fletcher 90]:

> *In response to Congressional direction, a quantitative, analytical review was completed of interactive videodisc instruction applied in Defense training and in the related settings of industrial training and higher education. Over all instructional settings and applications, interactive videodisc instruction was found to improve achievement by about 0.50 standard deviations over less interactive, more conventional approaches to instruction. This improvement is roughly equivalent to increasing the achievement of students at the 50th percentile to that of students currently at the 69th percentile. An improvement of 0.38 standard deviation was observed across 24 studies in military training (roughly an increase from 50th to 65th percentile achievement). An improvement of 0.69 was observed across 14 studies in higher education (roughly an increase from 50th to 75th percentile achievement). Interactive videodisc instruction was more effective the more the interactive features of the medium were used. It was equally effective for knowledge and performance outcomes. It was less costly than more conventional instruction. Overall, interactive videodisc instruction demonstrated sufficient utility in terms of effectiveness, cost, and acceptance to recommend that it now be routinely considered and used in Defense training and education.*

In general, while traditional instruction has a lower cost to get started, the cost for repeated deliveries and preparation for those deliveries will be relatively constant. By contrast, the cost profile for developing a computer-based solution will have a large spike in the initial effort that

continually lowers as the development cost is amortized over the lifetime of the product [ATP 85].

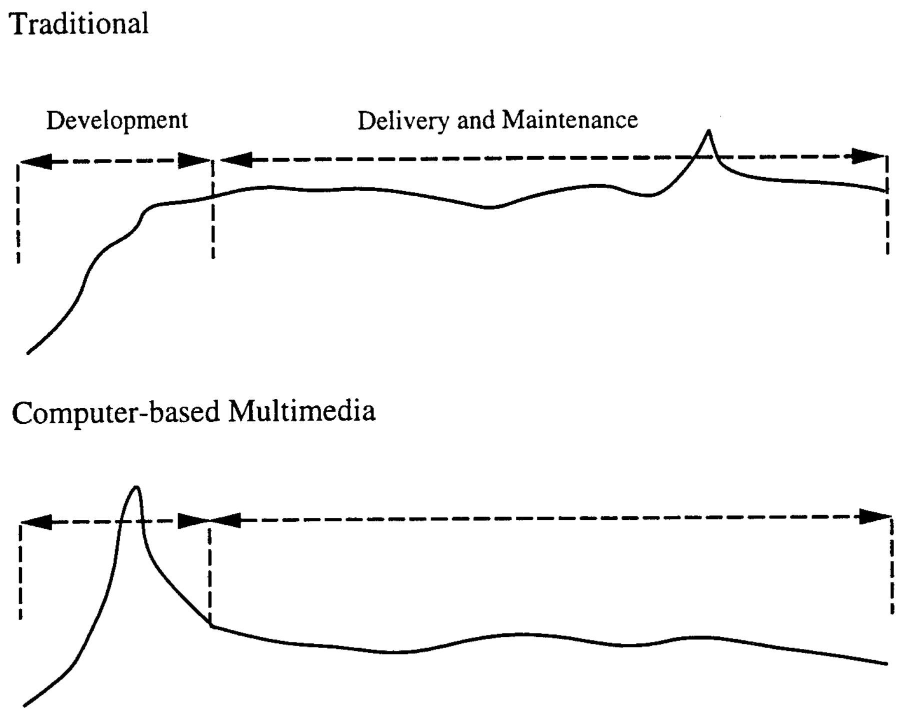

Figure 1: Course Development Cost Profiles

Taken together—the high level of learner interactivity, the richness of the latest multimedia features, and the improvements to networks and CPUs—computer-based training solutions have come into their own. It is now possible to provide students with an engaging, skill-based learning experience using some combination of multimedia features in virtually any domain imaginable.

3.1 Development Issues in Multimedia

There are at least three well-known models in the interactive multimedia development process:

1. turnkey in-house development
2. turnkey vendor development
3. shared in-house and vendor development

Option number 3 is the most common, and it too is divided by degrees that range from partial to total participation on the part of the purchasing organization. In any of these cases, the same competencies apply. Sharing of responsibilities between organizations increases risk, from communications, differences of management style, physical distances, and a host of other factors. In almost any case, the decision to build an interactive multimedia system will be

an organizationally shared responsibility. It is therefore in the interest of the managing organization to understand the hardware and personnel issues associated with the development process. The contracting organization that is sizing up potential development vendors must understand the vendors' capabilities in both the equipment and the people they intend to employ.

3.2 Working with Vendors

Because developing multimedia is inherently complex, the contracting organization must understand development costs, lead times, and the minimum competencies that the vendor should be able to demonstrate. Sections 3.2.1 and 3.2.2 provide a set of issues that the contracting organization should look for in selecting a vendor. If one or more of the hardware components seem suspect, if certain team roles are missing, or if price quotations are out of line with what is shown in this report, the vendor is probably ill suited to manage an interactive multimedia project of significant size. Naturally, a proven track record is persuasive, but experience alone cannot be used as a guarantee of success.

3.2.1 The Hardware

The hardware for creating and delivering multimedia applications must be chosen with a forward-thinking perspective so that the solution is extensible and maintainable. Even with careful thinking, market changes in multimedia systems are occurring so rapidly that even the most informed developers are frequently caught by surprise. If there is a risk to pursuing large-scale course delivery through computer-based instructional strategies, it is this dynamism of the marketplace. The best advice in pursuing any advanced computer-based training system is to seek out the expertise of an experienced consultant and vendor/developer to help determine the appropriate configuration for the organization's needs. The vendor must have a very strong grasp of available delivery platforms with an eye to coming trends.

3.2.1.1 Delivery

The use of multimedia narrows the field to two primary candidates for delivery: Macintosh®- and Intel-based personal computers (PCs). Currently a computer capable of delivering multimedia programming can cost as little as $2,000 for a 486-based PC, or approximately $4,000 for a full A/V Macintosh (16 mb RAM, 500 mb hard drive, CD-ROM). The prices listed would undoubtedly be lower for bulk purchases. Obviously the field is much wider for systems using only text-based training or text with limited audio.

3.2.1.2 Development

The two most prominent authoring packages on the market are Macromedia Director® (street price approximately $900) and Authorware® (approximately $7,000). With any development platform, the possibility of creating runtime "players" exists for cross-platform delivery. The safer bet is to develop the software on a platform consistent with the target delivery system.

A complete professional development machine for multimedia Intel-based PC costs about $3,000. This would typically include at least 16 mb of RAM, a 486-66 DX/2 processor, a 1,024

X 768 monitor, and at least 1 gigabyte of storage memory either on a hard drive or magneto-optical drive. An equivalent Macintosh-based system costs approximately $6000, including PowerPC processor, a high-quality full-color monitor, and a gigabyte of memory. Of course the printing resources in either case add anywhere from $1,500 to $5,000, depending on the printing requirements of the project. Combined with a flatbed and other image-scanning devices, the total for either an Intel- or Mac-based multimedia development system will near $10,000 per system. In general, Intel-based equipment costs less than Mac-based equipment. There is, of course, ongoing disagreement among developers about the superiority of one development environment over the other.

In the normal case, there is at least one machine dedicated to a project of small-to-medium size (small = less than $50,000, medium = $50,000-$300,000). Projects of medium size will often require one central development machine and anywhere from two to four satellite machines for others on the supporting team: writers, image-preparation personnel, and so on. Therefore, the cost of hardware for any medium-sized development project will most likely not be less than $50,000 to establish a very basic development infrastructure. Add software costs to this, and the initial costs for a basic development configuration approaches $70,000.

3.2.2 People Issues

Any multimedia effort is a team venture. The developer should have at least the following functional roles: project manager, content expert, writer, computer artist, graphical user-interface (GUI) designer, programmer, and instructional designer. The contracting organization should view weakness in any of these areas as suspect. Typically, multimedia vendors are small, or are small subsets of larger software development firms. Established methods for qualifying vendors such as software capability evaluations will be difficult to match to most of these specialty companies, which are known in the multimedia publishing industry as "boutiques" because of their small size and resemblance to storefront retail operations.

3.2.2.1 Development Roles

Project manager: Strong project management skills are an absolute requirement for multimedia development of any kind. The project manager must be adept at determining the scope of the project before scheduling and must be competent at developing the schedule estimate based on the scope. The project manager must also be able to set customer expectations appropriately.

Content expert: The content expert is obviously essential to the creation of any instructional material. When interactive multimedia technology is involved, it is best if the content expert has experience with and understands the technology. Having a content expert who understands the technology on the team is an added bonus that allows communications to go more quickly and smoothly. The content expert will often turn up insightful methods to use the various media elements to best advantage. The content expert can often quickly discern where the media is interfering with the message being conveyed.

Writer: The writer often serves a role that is central to development of the project, often stepping over the bounds that one might associate with writing, at first glance. The writer often becomes involved in requirements elicitation, project organization, organization of materials, analysis of content, and other roles.

Computer artist: A computer artist processes or creates all of the imagery required to illustrate ideas, backgrounds, and text for the system. If the organization developing the computer-based multimedia system is competent in their personnel selection process, the artist will also have strong ability in computer-interface design. Finding these skills in one individual can be considered very lucky.

GUI designer: This individual must have a keen intuitive sense of design as well as formal training on how to understand and administer field trials for potential system users. The GUI designer is familiar with how people work with computers and how to use the computer screen effectively.

Programmer: Ideally, a programmer on a multimedia development team are capable of crossing boundaries with art and design. More typical; however, is the case in which these functions are separate, requiring team discipline and consistency in maintaining communications between members. There is often the need for someone with low-level programming skills to create specialized functionality to operate under higher-level COTs programs (such as Authorware or Macromedia Director) and multimedia elements such as digital video or large volumes of text.

Instructional designer: Instructional design is a consultive and quality-control function. It is an invaluable function to the educational design of any multimedia system. The instructional designer can establish and evaluate mid-project user tests and provide useful feedback as a result of those evaluations. An instructional designer should have strong facilitator skills and the ability to elicit requirements for the system. Often the instructional designer is a project manager as well, serving a central position in specifying the system, maintaining communications between project team members and the system customer.

3.2.3 Development Costing Guidelines for Computer-based Multimedia

Based on estimates from Anderson Consulting, Inc., one half-day of instruction will cost $277,500. Anderson's breakdown of these expenses is

Design and development	(300 days x $500/day)	$150,000
Administration and management	(60 days x $600/day)	$36,000
Video subcontract		$80,000
Direct reimbursables (travel, etc.)		$11,500

Estimates of the ratio of development time to user contact hours (also called *seat time*) are shown as follows:

Low	400:1
Medium	800:1
High	1200:1

Contrasted against a small multimedia-development firm, Visual Symphony, Inc.,[4] these figures are consistent. Anderson reports their typical hourly development cost at $75 per hour. Visual Symphony provides a range from $60 to $100, explained by the variation in the complexity of creating user interactions. Visual Symphony adds the further cost of front-end analysis (scoping) at a flat rate of $10,000.

3.3 System Maintenance

Because of the rapidly evolving state of multimedia today, the market should be approached with caution. While the prices of delivery platforms are becoming less expensive and the software to run on those platforms is becoming more available, the problems of relevance still remain. That is, off-the-shelf multimedia programs are unlikely to be relevant to a specific training need unless an instructor can adapt the commercial software package to fit the need. Development of multimedia still requires specialized development. Allen Communications, a prominent multimedia developer, has produced training for Air Force fighter maintenance and a system to teach fundamentals of running a business. Anheuser-Busch has a training program entitled "Sales Source 2000" that teaches "beer-selling basics." Electronic Data Systems, Inc. has a program that teaches inventory policy, procedures, charging, and troubleshooting. Boeing has a multimedia program teaching maintenance of the new 777 airplane. All of these are dynamic programs with many interesting features. Each of these systems is also "tailor made." So far, multimedia development is a job-shop process and requires a hand-in-hand relationship between the developer and the developing organization. Furthermore, it is not common for organizations to have in-house capabilities to develop multimedia. There are exceptions to this, however, such as Anderson Consulting.

When development is so specialized, maintenance is obviously an area of concern. At least three appropriate questions to ask before development are

1. Who bears responsibility to maintain and repair the system once it is deployed?
2. Will the contracting organization commit to learning to maintain the system, or will the developer be responsible?
3. How volatile is the subject matter?

4. A small multimedia development company in based in Pittsburgh, Pa.

Each of these questions must be carefully considered.

3.4 System Life Cycle: Long Term vs. Short Term

Clearly multimedia is an appropriate choice for a course with a long-term need. In the best case, a careful front-end analysis will reveal the longevity of the need. The contracting organization should establish a satisfactory relationship with a trusted multimedia developer. Such a partnership should enable courses to be created with maximum reuse of existing materials and code modules developed in initial projects.

In any case, the contracting organization should structure its agreement with the developer to retain rights to any software created during the project. Such an arrangement is typically documented in a standard agreement that permits the developer to reuse code on future projects for other clients but allows the contracting organization to have full access to any part of system code at all times.

3.5 Related Solutions in the Multimedia Family

The following descriptions involve one or more media elements that can be categorized as multimedia. Any one of these systems can present digital sound, images, text, video, or music, either in a piecemeal fashion or as an integrated instructional system.

3.5.1 Electronic Performance Support

EPSS are a kind of computer-based multimedia that are integrated directly into the context of work being performed. A recent application is a spreadsheet created by Lotus®. If, while using Lotus 1-2-3®, the user has a question on how to create a macro, a training module can be invoked. Because it offers so many possibilities to optimize on learning and performance outcomes, electronic performance support is gaining a solid following among technologically astute educators. Again, the same "platform" learning factors are in play: interactivity, situated experience, and learner adaptivity.

The issues surrounding EPSS are not intrinsically different from multimedia generally. Although these systems offer a great educational payoff, there are not many of them in existence, and creating them requires the proper front-end analysis to justify an organizational commitment to their development. Otherwise, there are exceptional examples for specific target domains such as the Lotus example above.

3.5.2 Hypermedia Information Services

Hypermedia is computer jargon describing the interlinkage of text and symbols to provide system users with the ability to move from one link to the next. This linking of information is intended to provide informational points of departure through large bodies of information.

The WorldWide Web (WWW) is now a prime example of hypermedia, whose use is expanding daily. With Internet hosts increasing at a rate of approximately 7 percent per month, network

usage is rapidly becoming commonplace and will undoubtedly be as common as the telephone in the very near future. Corresponding to this growth is the number of available information sources on the network. Currently there are WWW sites for information on the National Aeronautics and Space Administration (NASA), American Telephone and Telegraph (AT&T), Apple Computer, Software Engineering Institute, major U.S. magazines, the U.S. Patent Office, and many others. Creating curricula to use these resources is a new idea. It is possible to download entire multimedia presentations from the network. To date there is not a great deal known about teaching courses using the Internet interactively.

Currently, courses taught using the Internet are new and varied. One course developed at Gallaudet University has linked deaf students with another class at Rochester Institute of Technology; however, interactive use of the Internet for instruction is experimental. Its use as a resource with network news services, email, and specially created newsgroups is more than ten years old however, and in conjunction with rapidly developing WWW sources, the Internet stands to be an ever-richer resource for any instructor who has ready network access.

3.5.3 Just-in-Time Lecture (JIT)

JIT lecture is a very straightforward use of various multimedia technologies to store and retrieve lectures for access. The Carnegie Mellon University (CMU) Multimedia Lab is developing a standard process by which lecturers can easily record their own lectures in digital video to be organized by a topical outline for random access to lecture topics by students. The system is integrated into the CMU campuswide network, and students are able to submit questions to the instructor (or teaching assistant) through email. If a question is submitted by several students, the instructor will add more material to the lecture; otherwise the question is answered individually. Currently the system permits instructors to provide visual and audible email responses. The objective of the JIT development effort at this time is to reduce the current lecture production time from 40 hours to 20 within the next year.

3.5.4 Intelligent Tutoring

Intelligent Tutoring Systems (ITSs) are computer-based instructional systems that diagnose the responses of a user in order to make incisive remediations as a human tutor would. Although all indications are that multimedia would do nothing but improve such systems, ITSs can be used with or without multimedia. In contrast to standard computer-based training, ITSs do not follow a fixed set of responses to student errors. Their "intelligence" is in figuring out the "cognitive malady" of the student in the context of instruction. ITSs attempt to deduce why the student is making a specific error, for example a math tutoring system, would try to determine why a student was failing to add two numbers correctly. It would use analysis rules to make instructional decisions related to the domain. For example,the student might not performing a "carry" properly, or perhaps is not understanding "place value." In other words, the system reasons as a human tutor would about the causes of a student's problems and attempts to match this "diagnosis" to insightful tips and remedial commentary.

Building intelligence into a computer-based instructional system requires a skilled programmer who is familiar with expert-system and artificial-intelligence-based programming. Development costs have decreased as new tools have been developed, and the continual improvement of delivery systems is creating new possibilities for developing this type of system more easily.

3.5.5 Text-Based Computer-Based Training (CBT)

Most online tutorials (for example those using Intel-based PCs) are text based. While this kind of training is far less demanding in development than multimedia, its effectiveness as a training vehicle is limited by its lack of the richer features of full multimedia capability. Lack of full-motion video and images, the value of which has been described by Christel [Christel 94], places definite limitations on the educational environment. While the effectiveness of interactive video systems has been proven, I know of no major studies pertaining to the effectiveness of text-based, online tutorials. To the extent that they are interactive, they will undoubtedly have instructional value; however this would in most cases be highly procedural training.

3.6 The Multimedia Family of Solutions and Travel Reduction

Because of its potential distribution to any properly configured desktop computer system, interactive multimedia can virtually eliminate travel to classrooms. Multimedia can be delivered with or without a connection to a network. When delivery to a network is not feasible, a complete multimedia training program can be delivered on CD-ROM.

Figure 2 shows a currently available network configuration that permits full audio-visual functionality, including full-motion video on a 40-user LAN. This is not hypothetical. Starlight Networks® produces this hardware, and there is a slightly less powerful and reliable version produced for Novell®. In this configuration, students can work at their individual workstations independently in a cluster configuration or at widely separated sites.

Real-World Example

When a network is used, results of training can be downloaded to a mainframe using a modem. This type of configuration is currently being used by CSX Transportation for conductor training. Their system permits conductors to take portions of the required 8-hour program as they travel over a span of 26 cities. The CSX system includes full-motion video, animations, audio, and interactive examples and testing to teach the use of a new computer technology for work-order report that is to be installed in all CSX train cabs.

The network configuration used for the CSX application is not particularly complex. The following reflects current prices for one 40-user multimedia workstation configuration:

- $2,500 per workstation
- $8000 per 64 mb RAM server
- $4000 per 6 gigabyte hard drive
- $25,000 network driver software
- $8000 per switched hub

When the system requires five or fewer users per LAN (as with CSX), the switched hub is not needed.

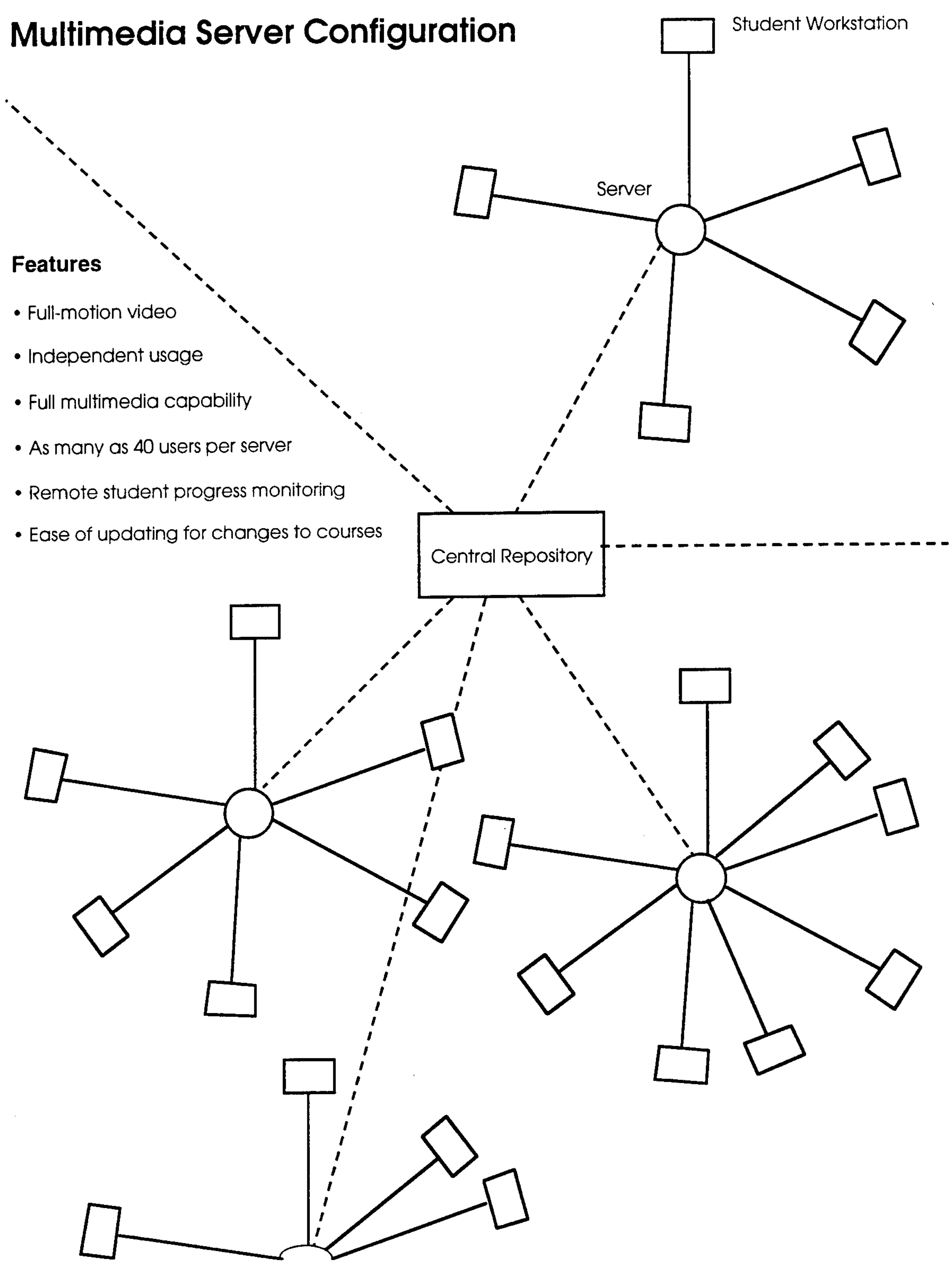

Figure 2: Multimedia Network Configuration

As a distance-learning solution, the CSX example demonstrates that training that utilizes state-of-the-art interactive multimedia can be delivered to sites that are separated by hundreds of miles, while at the same time providing centralized performance monitoring. Virtually any interactive multimedia that can be used in a stand-alone system can now also provide the benefits of the network as well.

3.7 Other Potential Distance-Learning Solutions

Outside the realm of the interactive computer-based systems, there are still the "tried-and-true" methods of course delivery. Videotape, satellite, and travelling lecturers have well-known positive features as well as certain clear limitations. For better or worse, these methods represent a "stepping back" from the revolutionary change implied in the current wave of advances in the computer-based systems. I consider these methods in the following paragraphs.

3.7.1 Videotape

Videotape has been available as an instructional technology for many years and provides us with many useful lessons in understanding the educational value of video in the new computer-based technologies. For instance, interactivity is essential. An inherent weakness of videotape is its slow rewind and fast-forward capability. While video can show us many things, it is only as good as the methods used to present the content. This holds true for the fanciest of technological solutions, from multimedia to intelligent tutoring to satellite instruction—success depends on the quality of the production. While this may seem an obvious point, it is remarkable how often this precept is ignored. The "talking head" video is one of the most common in educational fare and provides us with a landmark of "things to be avoided" as we venture down the technological highway.

3.7.2 Satellite

Satellite is a well-understood educational technology. Although it is not often taken advantage of, the potential for interactivity is great for satellite courses. For example, the satellite program managed through the Air Force Institute of Technology (AFIT) offers brief instruction on the development of course materials for satellite broadcast. Although the visual feed is one way, AFIT provides conference audio through phone lines. This enables the instructor to communicate with students and enables students to hear answers and explanations given to one another. At a cost of $200 per hour, not including a $50 technician's fee and course development costs, satellite is now facing stiff competition from computer-based distance-learning solutions in terms of the educational value added.

It is possible to have full, two-way communications through satellite at a correspondingly higher price than one-way video. Obviously, the interactive capabilities are improved with both two-way audio and two-way video; however, unless the audio and video are operating at a high display rate, communications can seem confusing and garbled. Real-time satellite communication is only as good as the preparation of the materials designed for the course and the pre-

sentation skills of the instructor. With no technical problems, two-way satellite provides the possibility of a "virtual classroom."

3.7.3 Lecturers On Site

Rather than taking the student to the course, we can also send the course to the student. As in one-way satellite delivery, the lecturer's use of interactivity can vary widely. As a facilitator, a classroom instructor can provide the highest levels of student engagement as are possible beyond one-to-one tutoring. The risk, however, is that the lecturer will use little or no interactivity. Many instructors are simply not comfortable with high levels of interaction with students. Classroom lectures are only as good as the planning and design that goes into them, and even with excellent designs, a lackluster instructor can ruin the experience. In general, any measurable educational outcome can be achieved using computer-based technology. Further, computer-based technologies guarantee a stable style and manner of instruction over time and for any number of classrooms. Additionally, articles in major interactive multimedia journals are providing examples of this technology used as a classroom support.[5]

5. A recent example appears in *Multimedia Today 3,* 1 (Jan.-March 1995): 57-60.

4 A Technology-Specific Analysis

Figure 3 matches each of 10 educational delivery methods with factors related to instructional effectiveness, development complexity, and associated costs. This figure is an educated guess of the relationships known and represents a combination of research, experience, and rules of thumb in the absence of hard science. Many of these technologies are new and developing rapidly. Most of the data supporting this figure comes from cases and field reports cited throughout this report. The purpose of the figure is to provide decision makers with a grounded overview of technologies and relevant implementation factors as of today. Because these are fast-emerging technologies, the data will likely be quickly dated; nevertheless, the data can provide valuable insight for today's decision space.

The following descriptions correspond to the factors listed across the top of Figure 3.

4.1 Potential Level of Interactivity

This category defines *interactivity* as the potential amount of time the learner is engaged in a task, actively pursuing an instructional goal. As stated earlier, educational researchers refer to interactivity in various ways, such as "time on task." Informally, we can think of various positive learning experiences in which students were alert and contributing to the educational process. The question this analysis seeks to answer is "To what extent is the technology capable of maintaining an interactive experience with the student?"

Of the systems listed, seven are fully capable of engaging students in a rich instructional dialogue. Videotape is obviously a one-way communication; while students may be engaged by a well-produced tape, for the purposes of this report I would not consider videotape interactive in the same sense as a dynamic classroom or multimedia experience could be.

4.2 Project Management in Development

There are differences in the amount of time required to manage the development of any new product. Instructional technologies are no exception, and today the differences are so wildly divergent that it is very easy to be caught unprepared. I intend this category primarily as a general warning about the amount of time needed to properly develop computer-based instructional systems. With or without the use of technologies, course development is time consuming and often difficult. Technologies of any kind add to this difficulty and complexity. In particular, interactive multimedia requires intensive planning and management activity, preferably with the help of software tools.

4.3 Availability of Delivery Platforms

This category defines the available means by which the instruction is delivered to the student. Specifically, this category largely refers to hardware availability: computers, satellites, VCRs, overhead projectors, satellite downlinks, and so on. Remembering that Figure 3 is a compar-

ison chart, we can say that lecturers are more readily available to deliver instruction than computer-based multimedia instructional systems, for example (even though this may not be the case in the near future). It is also important to note that the military has a large satellite infrastructure available for nationwide course delivery, which is more readily available for course delivery than computer-based instructional-delivery platforms.

4.4 Maintenance Estimate

Maintenance is defined as the required modifications made to existing course materials. The circles in this category provide a comparison of the amount of this activity required for the types of technologies listed. They do not answer the question of how many modifications will be required for any given course; rather, they are meant to make it possible to compare how much modification effort will be required once the course exists as a product. For example, even though individuals often share their lecture and course materials, these often undergo significant changes from one instructor to the next depending on instructors' preferences in emphasis and so forth. In general, computer-based technologies are less modifiable than human-dependent instructional systems (including satellite). This implies that

- Because of the relative difficulty in modifying computer-based instruction, course developers should carefully prepare materials for long-term use.
- While lecturers have the advantage of wide flexibility in modifying instructional materials, modification adds the risk that key instructional issues will be inconsistently addressed over the lifetime of a course.

In light of these considerations, for better or worse, there will in general be less maintenance of multimedia-based instructional systems and more maintenance for other human and computer-based instructional systems. Of course, content volatility is a consideration with respect to any course development effort; however, courses are typically a mix of volatile elements and static principles. Clearly, where substantial amounts of the content are changeable on a monthly basis, any computer-based technology will become a questionable option.

4.5 Delivery Cost

The cost of delivering a course includes personnel required in the classroom at the time of delivery, the cost of any printing or creation of materials required for the delivery, and any other overhead specific to the classroom. In Figure 3, all computer-based delivery methods are rated as relatively low. The on-site lecturer is higher because of required materials preparation and the lecturer's time. Satellite delivery is ranked highest because of the cost per hour for use of the facilities in addition to those costs associated with the lecturer and materials. Videotape is ranked lowest because it can be shipped to any site with access to a VCR and observed without cost other than the time taken to view the tape.

4.6 Overall Development Cost

This category refers to expenses related to the design, development, and production of education and training relative to delivery methods. Currently, there is a much development associated with any computer-based instructional education strategy. It is therefore an important consideration in planning for this kind of technology. Among the computer-based delivery methods, any that use multimedia will be at the highest end of development cost because of the many detailed activities involved. Comparing two computer-based methods, text-based CBT and multimedia, both will be complicated to produce; however, because text-based CBT involves only the use of ascii text, it will be far less difficult to create than multimedia. Using multimedia implies the creation or selection of photographs, voice, music, or video. For each element, there are processing steps involved and decisions, such as the scanning of photos, shooting of video and so on.

4.7 Potential Reduction of Travel

Each of the delivery methods listed has some potential to reduce the travel time. Regardless of the method of course delivery selected, we can assume that course developers hope to maintain high-quality instructional outcomes. In light of this assumption, the shading of the circles in this category answer the question "Which technology is best able to retain the highest level of instructional outcome even when the students cannot travel to the lecture itself?" Irrespective of distances, computers will deliver the same level of instructional quality that was programmed into them in the first place. The same can be said for satellite systems: depending on the instructional effectiveness of the instructor using a satellite, distance will not change the outcome.[6]

4.8 Potential for Materials Reuse

Reuse of materials is of obvious importance in product development. I found no evidence to suggest that one delivery method provides greater materials reusability than another. Computer-based instructional systems allow for the reuse of certain code routines used for student evaluation. Computer-based multimedia can provide the opportunity for reusing image libraries, evaluation routines, video, audio, and sound, *depending* on the nature of the course and how generic the need. More human-dependent instructional methods, such as satellite, provide for the possibility of reusing lecture materials and even interaction methods *depending* on the inclination of the instructors to do so.

4.9 Overall Estimate of Instructional Effectiveness

Based on the instructional factors provided earlier in the report, my intention for this category is to provide a general view of the capability of the delivery methods to be instructionally effective. My assumption here is that the more the instructional medium is capable of providing

6. In the absence of scientific data to refute the idea, this seems like a reasonable assumption.

sustained involvement and attention to specified learning tasks, the more effective it is. For example, videotape, even when used with a specialized interactive videotape machine, cannot provide for the same degree of student involvement because of the relatively long seek times associated with it.[7] The student has to endure lengthy waits while the machine rewinds the tape. While two-way satellite would seem to be able to provide near-classroom-style fidelity, in fact it does not, because of variations in transmission speeds. These variations are often disruptive and distracting to dialogue. Intelligent tutors, EPSS, multimedia, and human-based on-site instruction all have the potential for rich and attention-demanding interaction with the learner.

4.10 Potential Learner Adaptability

The human tutor is an accepted baseline measure of instructional effectiveness against which instructional technology has often been compared [Anderson 85]. Tutors are able to analyze the difficulties of their students and make adaptations to their teaching strategies as circumstances arise. The rankings listed show that four of the computer-based technologies are the most highly adaptable to the individual learner. Because an instructor's ability to adapt to the individual is constrained by the number of students enrolled, on-site lecturers have less adaptability. Of course this also applies to satellite technology because of its relative dependence on the instructor and class size in addition to the separation of instructor from the class. Text-based CBT has the potential for adaptability, but adding this capability would push this technology into the intelligent tutoring category. (To reiterate, *text-based CBT* is defined for the purposes of this report as a label to describe text-based computer tutorials with branching capability, having no capacity to adapt to specific learners.) Just-in-time lecture provides random access to segments of lectures, offering some learner adaptability; however, these adaptations depend on the learner's ability to seek out the information. By contrast, videotape simply does not adapt.

7. Despite certain specific instances where individuals have created usable random-access videotape systems, this technology can rightly be thought of as obsolete.

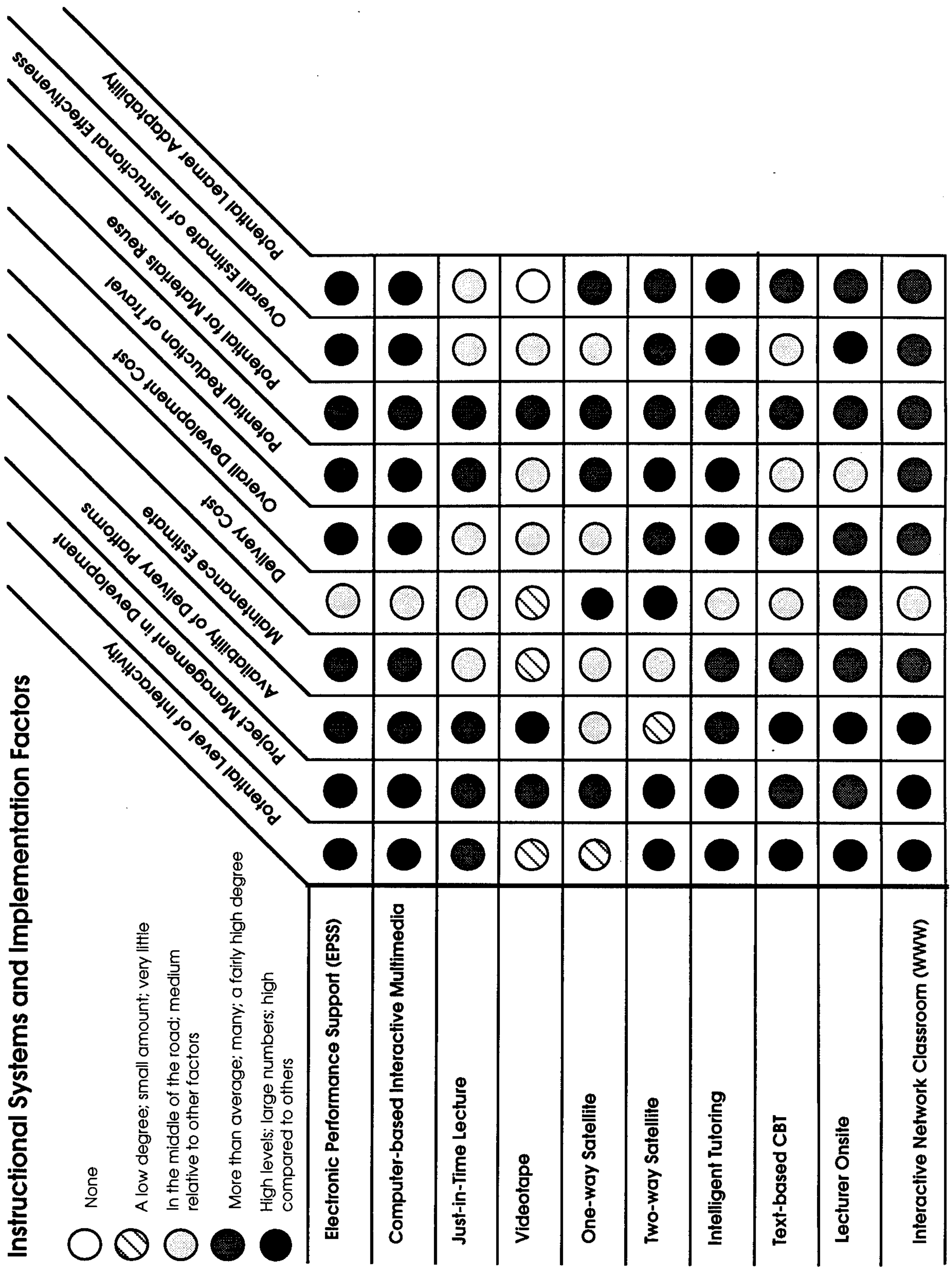

Figure 3: Estimated Instructional and Development Factors

5 Summary, Recommendations, and Conclusions

Based on the discussion of core educational issues and the available technologies, our task becomes one of "mix and match," based on how much money there is to spend against the learning outcomes that are to be achieved.

5.1 Summary

There are two primary considerations in selecting an instructional technology solution: learning factors and delivery logistics. The technology selection objective, therefore, is to optimize on the best and most appropriate learning factors while minimizing the negative effects of the logistics involved in delivering instruction.

Prominent among the learning factors are

- interactivity
- learner adaptability
- situated learning
- retention
- volatility of instructional content
- consistency of training quality
- overall development cost
- existing hardware and software infrastructure
- ease of maintenance
- potential for course participant travel reduction
- potential for course content reuse

To provide interactive multimedia functionality, the computer infrastructure must be adequate. Depending on the types of multimedia services that an organization wishes to provide, the possible delivery mechanisms can range from $1,700 to $6,000 apiece. It is possible to provide an infrastructure capable of supporting all of the top-of-the-line multimedia features, such as full-motion (hardware-assisted) video, in a LAN configuration, or to provide only a limited set of these features, where a LAN may or may not be a part of the system configuration. A hypothetical 10-user LAN supporting full-motion hardware-assisted video (30 frames per second) as well as any other available multimedia feature will cost approximately $65,000. This price would include 10 workstations, a 6-gigabyte server and set-up charges.

Using Intel-based systems, full-multimedia capability can be made available including an inboard CD-ROM drive and modem on any desktop for under $2000. A machine having these capabilities permits access to existing WWW offerings, the Internet, and the use of CD-ROMs. This is not to paint an overly rosy picture. Obtaining access to the Internet and assuring reasonable system performance (speed) in downloading images and other types of large-data

items will require the purchase of the appropriate high-bandwidth connections,[8] adequate local host storage,[9] server software, and any other ancillary support devices such as Ethernet cards for user machines.

The network technologies required to deliver WWW and corresponding multimedia functionality to the classroom are well understood and will require a separate analysis considering the numbers of students that would participate in pilot courses. The major technical considerations in this regard will revolve around the number of users and their influence on network performance. Solutions must be scalable to larger numbers of students, with an eye to hardware improvements and upgrades.

5.2 High-Level Recommendations

5.2.1 Build an Educational Infrastructure

The purpose of this infrastructure is to support WWW access and provide for potential multimedia course distribution. Given the rapidly growing availability and shrinking cost of computer-based multimedia hardware and software, the time is ripe to establish a technological infrastructure that will open the door to the full range of multimedia offerings and anything on the WWW—all at one time. Among the rapidly growing number of subscribers to the WWW, there is no argument as to the horizons that this technology is opening, especially from an educational standpoint. Further, there is already a well-established precedent among American universities, where the value of the networks is inarguable.

5.2.2 Assess Information Repositories to Be Made Available Through the WWW

There also must be a forward-thinking assessment of the target workstation suitable for use both online and as a stand-alone system with full multimedia capability. It is now possible to purchase a complete multimedia workstation with large storage capacity and inboard modem for $1,700 in the consumer marketplace. This cost implies that with an understanding of the geographical distribution of the student population, that both LAN-based and stand-alone system configurations are feasible.

5.2.3 Pick a First Target for Computer-Based Multimedia

Establish a candidate project for implementation as a multimedia course. Remembering that a rule of thumb is that complexity costs more, determine a relatively long life-cycle, low-complexity course for implementation.

8. Ethernet, token ring, or equivalent

9. greater than 2 gigabytes at a minimum

5.3 Lower Level Suggestions

The following represent four possible approaches, as well as a framework for thinking about strategies of implementation. These are not exhaustive, but each represents a plausible set of choices, assuming that the basic system infrastructure is in place. As stated in Section 1.2, assumptions about the organizations to which these suggestions apply are the following:

- A certain amount of instructional infrastructure is already in place.
  - Satellite hardware and system support is readily available for wide-scale transmission of one-way and potentially two-way educational offerings.
  - The existing computer hardware base is composed largely of Intel® microprocessor-based machines, capable of delivering text-based instruction [computer-based training (CBT)].
- The organization is willing to explore the possibility of expanding the existing infrastructure to include technologies capable of interactive multimedia[10] and other advanced computer-based instructional solutions.

5.3.1 Strategy 1: Network-Distributed Computer-Based Training

This strategy consists of downloading low-level interactive training courses to LANs for use at student terminals.

Objective

Engage in a slow migration to computer-based course delivery. This plan would optimize existing capacity while building for greater infrastructure capacity in a "slow-growth" scenario.

Features

Many sites across the U. S. currently have 386-level, Windows-compatible computers available for course distribution. These machines are capable of communication with the Internet or LAN.

Advantages

Given the current state of practice, this option could be put in place quickly. It would enable an organization to run test cases to determine the efficacy of the approach on a limited basis.

While the development cost for any interactive, computer-based instructional solution always has the drawback of initial development cost, text-based CBT is the least expensive of the existing computer-based instructional approaches in this regard. And it holds the edge of interactivity as an instructional approach.

Limitations

Text-based CBT is among the least interesting of current possibilities in existing instructional technologies. Although studies on the effectiveness of CBT indicate that it is capable of meet-

10. *Multimedia* is defined here as digital audio, video, images, music, text, or animation that is integrated on a computer system.

ing basic training requirements, it is more limited than full-function multimedia on educational grounds.

Costs

Training developed for CBT will have to be developed according to the specific needs of the organization. This development implies creating the software in conjunction with a developer and the management of all the activities thereof.

5.3.2 Strategy 2: Combined Semi-Interactive Instruction

The combined semi-interactive strategy is designed primarily to reduce travel costs without a loss of instructional effectiveness.

Objective

Map current practice into a combined satellite- and computer-based instructional solution.

Features

This approach would utilize any existing satellite infrastructure in combination with network-distributed exercises and tests. For any organizationwide distributed system for delivering courses, an advanced record-keeping system will have to be created.

Advantages

This approach is optimized to take advantage of existing resources. The only new programming required would be related to the network-distributed aspects of the approach, which would provide students with simple text-based exercises and tests in which results would be stored in a central file server.

Limitations

Although interactive video communications by satellite and computer network are improving, neither is easy to use. Frame-display rates for two-way satellite often make meetings with only a few individuals somewhat confusing. This becomes even more problematic in scaling to full course implementations. Existing courses will require modifications for use in this new scenario as well. Costs are high for delivery.

Cost

Costs associated with this approach include the uplink time, course test and exercise development and design, programming for those materials, and lecturer preparation time.

5.3.3 Strategy 3: Computer-Based Multimedia

Currently all features of any multimedia system can be used on LANs linked to a central server or as stand-alone systems. Full-motion video, sound, animation, music, and a high level of interactivity are all available at relatively low cost.

Objective

Create an infrastructure to support future network-based WWW access and multimedia-based course development.

Features

This delivery configuration will suit any scale of multimedia delivery. All the attributes of multimedia can be delivered to student workstations on LANs or on stand-alone units. To support the capabilities of the WWW, it is necessary for the target workstations to have full multimedia capability.

Advantages

Multimedia provides effective instruction. By virtue of the range of possible presentation styles and devices, multimedia provides a learning environment with possibilities previously unknown in the history of education. With proper development, interactivity is built into course delivery, and the richness and variety of the learning environment is enhanced by photographic-quality images, full-motion video, sound, and music.

Limitations

Initial multimedia course development is expensive, requires management and supervision, and requires relatively long lead times to create a successful system. Further, poor multimedia is always a potentially costly risk. Developing multimedia programs from scratch is a complex process that requires careful expert supervision.

Cost

As stated above, multimedia has many initial costs associated with it. These costs are primarily incurred as functions of course and project planning, creation of graphics, animations, and screen design. Video used in multimedia is no more or less expensive than in any other video production. Programming time is somewhat more extensive than with a CBT program, although the nature of the work is not substantially different. If development capability is not created within the organization, there will be costs incurred to supervise a developing subcontractor. Building the capability in house is difficult, with a steep learning curve.

5.3.4 Strategy 4: Real-Time Internet-Based Instruction

The Internet is perhaps the fastest growing educational technology in existence. According to statistics gathered at Software Engineering Institute (SEI), the Internet is growing at a rate of 7 to 10 percent per month. Corresponding to this growth rate are the tools for navigating and communicating by the network. Carnegie Mellon University is currently producing a computer-based tool for collaborative distance work. Individuals may see one another by video as well as being able to write and critique documents in real time. While this technology requires that each workstation have its own video card, it is only a matter of time before this type of system is commonplace for office work, and there is no factor in particular that would prevent its use for classroom interaction.

Objective

Provide an easy-to-use Internet front end for interactive teacher-student dialogue.

Features

Collaborative work systems are not new; however, collaborative writing tools that include video are only now becoming available for multichannel communications on the Internet. With multi-party communications, an instructor and class can participate in dialogue from multiple distant locations. Various programs currently exist to support this kind of interaction, and the technology to facilitate this type of network-based dialogue is rapidly improving.

Advantages

Relative to other computer-based distance-learning options, this option can be made available with less effort. No new materials would have to be developed to conduct a class. In this sense, the Internet is rapidly becoming like two-way satellite communications. Materials developed specifically for this medium require some modification to optimize on the dialoguing aspect, but no special-purpose materials such as graphics, animations, or screen designs would have to be created.

Limitations

There will be hardware required to make full-duplex video and audio communications possible. If the implementation platform is Intel based, video frame rates may be fewer than 15 frames per second. Video display on computer terminals will in all likelihood be less than full screen for at least one year. Currently the size of these displays is either 320 x 240 (quarter screen) or 160 x 120 (one eighth). Naturally the size of the video display window is a limitation relative to any workstation's monitor size.

Cost

The cost for this solution will stem primarily from hardware purchases and network installation. Each unit would require a video card plus enough memory and CPU to provide students with equivalent interactive capability.

5.4 Conclusions

The rapid rise of the Internet and computer-based multimedia have opened the door to educational delivery possibilities that have never been see before. Students of all ages can now have access to video archives of lunar travel, photos of the Shoemaker-Levy Comet as it crashed into Jupiter, international communications, and archives describing foreign peoples in full color, with music and voice. These technologies are no longer restricted to elite research organizations. Soon it is likely that they will be in homes all across the United States. The nature of training and education will be changed forever as a result. Organizations are no longer asking questions that begin with "If we get on the Internet..." but rather they assert, "When we get on the Internet..." Because of the intense demand of this user population, the very nature of learning will change. The demand will be on improved interfaces and more interesting and dynamic computer-based experiences.

This report has only touched upon satellite instruction. No matter which final distance-learning strategy is selected, it appears that satellite instruction is always a possibility, given the ready resource that it is. The cost for satellite delivery appears to remain relatively constant and is expensive. In my estimation, satellite- and computer-based delivery solutions will be competitive in the short term; however, the cost of satellite delivery will remain high while the cost of network-based solutions allow for reduction through amortization of their initial development cost.

The military has in many instances led the development of leading-edge educational technology, and should continue to do so. To pursue a comprehensive strategy to employ these technologies effectively, however, sufficient resources must be committed to provide not only adequate materials, but human energy as well. The change to network-based multimedia is inevitable. The questions that remain pertain only to the logistics of the implementation.

Appendix A Course Example

This appendix describes a protocol to assist in selecting from among instructional delivery strategies.

A.1 The Questions to Ask

With any project development where training *may* be an issue, question number 1 is "Do I have an instructional problem to solve?" The question can have subtle implications—to answer it, one must make a delineation between instruction and the providing of information. In terms of this report, *instruction* is defined as a set of activities designed to impart verifiable changes in student's cognitive or procedural abilities toward specific learning objectives. By contrast, *providing information* is a communication designed as a one-way transmission of ideas. In other words, providing information requires no verification of its effectiveness in accomplishing the goal, whereas in this context, instruction does.

Once the decision is made regarding instruction vs. providing information, it becomes appropriate to ask whether technology might provide some benefit to the course delivery. Because current technologies are proven to be of benefit in many instructional contexts, it is not premature to begin examining this question before content development, because many times there is a purely logistical component to the technology question. For example, if students are widely dispersed geographically and instructor resources are low, some form of distance-learning technology should be considered.

The next set of questions to be addressed revolves around content development. Instructional systems design (ISD), as defined by various authors,[11] assumes a fully integrated approach to curriculum development that includes the following steps at a high level:

1. Identify instructional goals.
2. Conduct instructional analysis.
3. Identify (student) entry behaviors.
4. Write performance objectives.
5. Develop criterion-referenced test items.
6. Develop instructional strategy.
7. Develop and select instructional materials.
8. Design and conduct formative evaluation.
9. Design and conduct summative evaluation.

11. Prominent among these are Walter Dick and Lou Carey of Florida State University [Dick 85].

While the precise implementation of these steps may change from one instructional designer to another, ISD is based on a set of learning principles that have become commonplace among instructional-design professionals.

While it is beyond the scope of this report to provide an exhaustive discourse on each part of the ISD model, there are assumptions of the model that have a direct bearing on the instructional selection process. For example, ISD always assumes that a set of learning objectives must be established. At first, this often amounts to identifying "key ideas," or what otherwise might be called the *conceptual core* of the curriculum. Broadly speaking, the question in this phase of development is "What set of understandings do I want my students to have once they have finished with the curriculum?" Often a curriculum committee or other team brainstorms these ideas. At first they may be identified as simple two- or three -word labels, such as *partial differential equations, linear algebra, key signature, color mixing,* etc. In other words, in this part of the curriculum development a high-level set of ideas within a domain is articulated.

Once the set of ideas is elaborated satisfactorily, relationships between the ideas should be determined. This phase assumes that, in general, students learn best when ideas are presented in a simple form at first, with more complexity introduced as this knowledge is integrated with new information and varied contexts. As such, the ISD model advocates organizing a map of the concepts to show these relationships explicitly. For example, in Figure 4 on page 41, the high-level concepts are organized from simpler to more complex. Instructors might argue about which ideas are more difficult and which ones belong first in the curriculum, but the value of the visual representation is not in question. Further, the "concept map" can be augmented to show how the ideas are related to one another in the horizontal direction as well. In Figure 4, the relationship of variable assignment in structures needs to be accounted for.

Next, for each of the concepts outlined, behavioral objectives must be defined. An assumption of the ISD model is that both physical and cognitive actions can be assessed only by using behavioral indicators.[12] Therefore, the curriculum developer must identify the exact nature of the student's desired performance for any level of knowledge.

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12. Hence Bloom's Taxonomy [Bloom 56] is entitled, "Taxonomy of Educational Objectives: Book 1, Cognitive Domain."

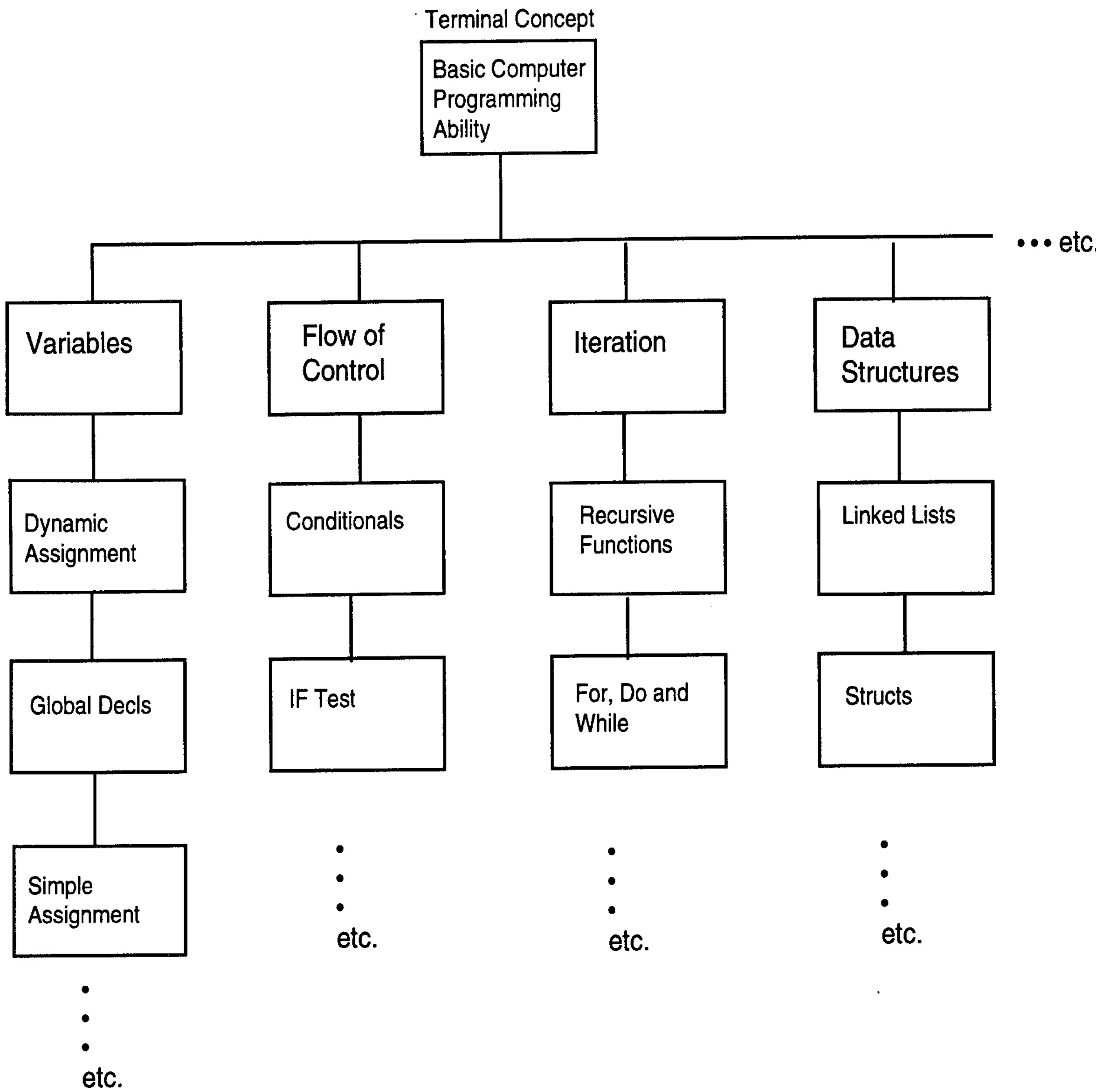

Figure 4: Concept Map

A.2 Example for a Specific Course

As a first example, consider critical competency 1 shown in Figure 5. This critical competency is focused on Bloom's level 1 as the target cognitive implementation level. The objectives for this competency are also listed in Figure 5. To create a more detailed picture of the classroom implementation of the critical competency and how it relates to Bloom, there must be a precise description of the activities carried out by the students.

1. Risk Management

Critical competency 1: to identify typical software-acquisition risks for systems, select appropriate risk-mitigation strategies, and evaluate the relative merits of those strategies

Top-level enabler 1: the ability to evaluate acquisition programs, identify risks, identify associated risk-mitigation approaches, and adjust acquisition plans to incorporate risk-mitigation approaches

Enabling knowledge

1K1: concept of "risk"
1K2: risk-identification processes
1K3: risk-assessment processes
1K4: risk-reduction strategies
1K5: problem-solving techniques.
1K6: laws, regulations, and DoD policies pertaining to the acquisition of software-intensive weapon systems; command, control, communications, and intelligence (C3I) systems; and automated information systems (AISs)
1K7: common software-acquisition risks
1K8: role of working groups in risk management
1K9: software development processes
1K10: risk-management organization

Enabling skills

1S1: identifying sources and types of risks in software-intensive system acquisitions
1S2: identifying the causes of known software-acquisition risks
1S3: establishing and applying a process for recognition and awareness of software-acquisition risk
1S4: evaluating contractor risk-management processes to determine the extent to which they are consistent with and support the program risk-management strategy
1S5: predicting the effect and consequence of a risk event
1S6: estimating the probability of a software-acquisition risk event
1S7: developing software-acquisition risk-reduction strategy
1S8: evaluating software-acquisition problem-solving techniques to determine the extent of their effectiveness in reducing program risk

Figure 5: Sample Objectives for a Course in Risk Management

Given the "enabling knowledge" provided from items 1K1 through 1K10, what will be the exact actions and success criteria expected of students when they carry out enabling skill *1S1: identifying sources and types of risks in software-intensive system acquisitions*? We can assume that there is more than one way of assessing software acquisition risks. Is there more than one way of assessing student proficiency at doing so? Therefore, the exact nature of an in-class exercise must be specified, not only to meet the requirements of the ISD model, but in the case of the use of interactive technologies, to provide information to developers.

A.2.1 Technology and a Classroom Example

A further breakdown of knowledge requires the following further clarification:

Learning Objectives 1S1K1L

The student shall list four sources of software-intensive system cost-estimation risk and for each source identify the a) associated possible risk events, b) probability of those risk events, and c) possible consequences of the occurrence of each risk event.

The instructional method listed for this objective is: "class discussion followed by student participation in providing 4 or 5 examples to complete the following outline on the white board." The "white board" example is as follows:

Source	Possible Risk Event	Probability	Possible Consequences
Ambiguous statement of work	Cost estimation low by a factor of 4	High	Contractor exhausts management reserve. Reduced capability in delivery system. Late initial operational capability Program manager relieved

Table A-1: Cost-Estimation Risks

A.2.2 Samples of Instructional Technology Application

Given the requirements specified above, a learning technology developer must ask several questions:

1. Given the nature of the classroom interaction, is there a practical role for learning technologies in this scenario?
2. If technology is to be used, how will it serve the content?
3. Which technology best serves the need?

Assuming that we determine that some form of instructional technology will be used, we begin to look for answers to question number 2. To use any form of instructional technology, we must at the outset determine its role from the standpoint of logistics. Will it assist the instructor, or do we actually wish to offload portions of the overall curriculum entirely?

A.2.2.1 Satellite

As stated earlier, satellite offers many of the features of a normal face-to-face interaction with an instructor, depending on the capability of the satellite system. Satellite capability has a range that permits full two-way audio and video potential, one-way video/two-way audio, or just one-way video and audio. In almost any current classroom use of satellite, the most likely configuration will be one-way video/two-way audio, because of the expense of full-duplex satellite and the inadequacy of one-way usage.

With either of the interactive satellite configurations, the interaction between instructor and class could be carried out more or less in a fashion like classroom lecture and discussion. Because the instructor is separated by distance and will in most cases have no visibility into the classroom, this presents some obvious limitations. For example, in the likely case of one-way video/two-way audio, the instructor will have to keep a list of the students' names to refer to during instruction. Obviously this is less conducive of interaction than line-of-sight visibility.

A.2.2.2 Interactive Multimedia-Based Solutions

Interactive multimedia opens the door to many options for the classroom. The following paragraphs describe potential levels of multimedia implementation for classroom support.

Classroom Support

For instructors who are not particularly comfortable with group dynamics, performance support can be engineered to assist the teacher in real time. One relatively simple use of this technology is as a video repository. As an example, the instructor could select a video segment showing a form of environmental hazard, followed by a question to the class: "What is the proper procedure for disposing of this class A hazard?" Students and instructor would then discuss a solution. The instructor could then demonstrate the effects of the students' selections.

Using interactive multimedia in this way is no different from using videotape as classroom support with the following important exception: The computer permits real-time classroom interaction because of its rapid random-access capability. Videotape is simply too slow. If the instructor were to try to use a standard videotape to recreate this level of interactivity, not only would all the appropriate tracks have to be indexed, but the instructor would be left to find them all using the fast-forward button on the VCR—the class waits as the VCR scrolls tape. Using the computer's rapid access time and database features, the instructor could predefine paths through video segments that contain useful illustrations of concepts that would otherwise be difficult to explain or demonstrate.

In this example, one of the procedures selected by students could easily cause (in video) an explosion, acid spill, contamination of the water table, and so on—experiences no one wishes to see played out in life. This kind of dramatic example provides rich opportunities for further discussion and debate in class. To those with experience in videodisc or video instruction, this kind of classroom multimedia is not new, but it is effective, and the random-access capability permitted by the computer makes using video in this way practical and easy.

This basic form of classroom assistance using interactive multimedia is among the least complex and least costly to produce. Nonetheless, as with all multimedia, there will be greater initial expense than with traditional classroom approaches. As with any course development effort, however, multimedia development should begin with an initial assessment of the needs and requirements of the system in which the proposed instruction is to be used. This analysis is called a *front-end analysis* or *needs assessment.*

Using the sample course objective on page 43, the emphasis for an interactive multimedia system would be to provide a resource for instructors to enliven the activity of populating the

whiteboard diagram. For example, the instructor could create a repository to play out various crisis scenarios related to poor cost-estimation practices. These could be illustrated in video or by using photos, illustrations, animations, or any other combination from the multimedia armamentarium. These scenarios could be stored on either a compact disc or computer hard drive. With the addition of a user interface, the instructor could provide the class with cost-estimation scenarios and ask for student opinions about "What would happen in the case where I would have 'ambiguous statements of work'? What are some of the problems I might encounter?" Working together to create a usable interface and to capture the appropriate variables in the cost estimation domain, the developer and instructor could create a repository of powerful examples that could be made available to teachers and students on demand.

In the case of cost estimation, instead of merely populating a whiteboard with appropriate entries, the class would now be able to propose strategies and witness some of the unfortunate consequences associated with poor cost estimation, and to discuss them with an expert instructor in class, thereby avoiding crises in real life. This approach is strong from the educational point of view, because the more realistic the instructional experience, the more likely it is to be remembered.

The main limitation to creating multimedia tools is the expense of producing specialized video, images, and animations, as well as the accompanying programming. Clearly, any analysis preceding this form of development has to consider the shelf life of the educational product and the nature of the materials being produced: How generic are they?

A classroom-support video repository such as the repository I have described would allow the possibility of materials being shared and reused, as well as the creation of a generic interface that could allow instructors to define their own specialized load-and-play curricula.

The question instructors should ask themselves in approaching interactive multimedia is "What would instantaneous access to graphics, sound, and video do for me in my classroom?"

Instructors are often their own best technical engineers. A recent article in *Multimedia Today* [IBM 95] describes Dr. Jack Wilson's use of multimedia in his physics class at Rensselaer Polytechnic. Dr. Wilson describes the following scenario utilizing various technological elements in the classroom:

> *During our acceleration-due-to-gravity session, we videotaped a student throwing a ball. We digitized the video directly into the computer and made it available to every student workstation over the network. Students then analyzed the motion using the online scientific tools. Next, students created a spreadsheet illustrating the ball's position versus time data, and then plotted their results on computerized graphs. All in one, two-hour block.*

Joe Molino, the IBM consultant with Rennselaer, is quoted as saying, "Rather than separating the functions of lecture, recitation and laboratory, the new physics format allows instructors to move freely from one mode to another" [IBM 95].

To create multimedia tools to assist in the classroom presentation, decisions must be made about the kinds of illustrations that would enhance the students' grasp of the content. As suggested, the best examples are drawn from real life. Such decisions are most often made at a creative meeting between the developer of the multimedia tool and the content developer.

The Just-in-Time (JIT) Approach to Interactive Multimedia

Using the JIT approach would simply entail recording the lectures of the instructors with a video camera, digitizing them, and indexing their content according to a topic outline prepared by the instructor. The lecture and indexes would then be incorporated into a user environment that permits electronic mail to the instructor (or assistant) so the students could ask questions. The system performs a first-pass analysis on the student's question to determine whether it has been asked and answered in the past using certain natural-language analysis techniques. If the question has been asked in the past, the system answers it automatically, using the answer already stored in its database of answers created by the instructor. If the question has not been asked before (or the system cannot analyze it accurately), the system passes it along to the instructor to answer in electronic mail.

Of course this method does not provide for any real-time classroom dialogue with the instructor, and therefore lacks the benefit of these dynamics. Relative to more elaborate uses of multimedia, this approach is inexpensive to produce, allows for network connectivity, provides a direct link to the instructor by electronic mail, and a provides a consistent reference for course information through the stored lecture.

Stand-Alone Interactive Multimedia Systems

Any stand-alone, computer-based instruction derives its strength from the curriculum and the richness of the intellectual content. When a stand-alone system is created, the effort *must* be a collaboration between the programmer, graphics specialist, instructional designer, project manager, and primary content developers. To be effective, stand-alone systems must be engaging and task intensive. These systems are used to best effect when they simulate events and ideas that are difficult to express in words alone. To achieve a high level of effectiveness using this medium, there must be an exacting analysis of the conceptual content of the course, planning of the illustrations of the tasks and presentations, and creative brainstorming to determine an overall approach to teaching the curriculum. This effort requires a complete translation of the curriculum from a facilitated discussion or lecture into a wholly different paradigm.

Given the example provided on page 42, there would be a need to determine how best to get across *ideas* at the level of the "top-level enabler." The question to ask for enabler number 1 would be "What presentations and activities will best support the student's understanding of risk management?" At first, there is a need to know whether risk management has subparts. Are there other enablers beneath risk management that constitute prerequisite understandings? If we assume that risk management is the fundamental concept for the student to grasp, then the developers must work in conjunction with the content experts to determine an approach to teaching it.

For example, one approach might use video segments, graphics, animations, or audio to present a simulated environment. One such system, produced by Allen Communications, places the student in the position of managing a railroad. The learner must make decisions about real-estate purchases, right of way, legal considerations, budget decisions, competitors, and so on. The idea behind the system is to present the student with a realistic representation of the variables affecting a manager in real life, using an entertaining backdrop. In this simulation, students sometimes achieve great success and sometimes go bankrupt, depending on their judgments about new rail purchases or construction, contracts obtained, and so on.

For the risk management example, a series of video scenarios could be compiled illustrating the effects of certain variables and risk. The possibilities for stand-alone interactive multimedia systems are many, given the following set of enabling skills:

IS1: identifying sources and types of risks

IS2: identifying the known causes of software-acquisition risks

IS3: establishing and applying a software risk recognition and awareness process

IS4: predicting the consequences of a software-acquisition risk event

IS5: estimating the probability of a software risk-acquisition risk event

IS6: developing risk-reduction strategies for software acquisition

IS7: evaluating software-acquisition problem-solving techniques

Having identified the enabling skills, the next question to ask, according to the instructional systems design model [Dick 85], is "What instructional strategy will be used?" Using interactive computer-based multimedia, the instructor has a new set of possibilities available. Given the enabling skills above, the instructor attempts to capture the best way to "situate" the learner's experience such that it will have the greatest meaning and transfer of ability into the actual work context. Obviously, one way of accomplishing this is to simulate an actual acquisition environment. The task would be to create a scenario in which the learner would be put into a context, perhaps using video to accomplish this, and be forced to make decisions according to the risks that arise.

This approach creates a surrogate experience, allowing the user to make mistakes and see the consequences of those mistakes played out in a form that causes no disasters, but which is memorable to the student.

Consider the following scenario:

A student takes a seat in front of a terminal in an office. The system is running from a LAN, and all that is required of the student to begin instruction is to type a user identification and password. After the student logs in, the system invites the student to answer some questions concerning organizational affiliation, branch of service, type of assignment, and so on. After

conducting this interactive questionnaire, the system loads a scenario appropriate to the user's assignment and branch of service, based on pre-established curriculum requirements.

For this example, the student is assigned as a captain in the systems program office (SPO) for COBRA STARS, a fictitious airborne surveillance aircraft. Colonel Brighton is the program director, and the user will be assigned as a software division chief. In this role, the captain will be approached, on video, by a Mr. Johnson from THC Systems Inc. THC was tasked with producing a radar data processor (RDP) for COBRA STARS. The RDP is actually an integrated set of processors, each with a specific function relative to the signal-processing and decoding task, each processor having its own specialized software modules to drive it. THC named these individual processors *AMPS*.

In the original software requirements specification (SRS) for the system, all processors were to have 50 percent of capacity idle at all times during system use. Today there is a problem: The captain notices that in many instances, performance measures of the processors in the RDP are functioning at levels well over 50 percent. At the same time, Mr. Johnson assures the captain that the RDP is running within the specifications provided to THC by the Air Force.

In video, Colonel Brighton angrily demands that the captain get to the bottom of this problem, as he is convinced that the contractor is attempting to renegotiate the original specifications.

After this presentation of the conditions within the SPO, the captain (student user) is shown a menu of options representing possible courses to be taken given these circumstances. Among the possibilities are

- request for specifications for the RDP
- performance measures

The student may choose one or both of the options listed. Depending on whether one or both have been selected, the student is approached by an animated figure who suggests that analyzing the original performance specifications might provide some useful clues. However, if only one of the possibilities is chosen in the absence of the other, the student is simply presented with the opportunity to schedule a meeting. The possibilities given the student for this meeting include

- Meet with Colonel Brighton to discuss specifications.
- Meet with the contractor to discuss the specifications and performance measures.

For the case in which the student has not selected the opportunity to review the performance measures, and must now schedule a meeting, the captain is in effect walking into a trap. Whether the meeting takes place with the colonel or the contractor, questions will be posed by either the contractor or the colonel that will expose the captain's lack of preparation.

For the case in which "Meet with Colonel Brighton" has been selected, the colonel (in video) will ask, "What do the comparisons say?" If the student at the workstation provides no answer within a given timeout threshold or selects a menu option such as "I have not yet requested

that information," the colonel dismisses the captain brusquely with, "At least next time prepare yourself before you waste my time, Captain!"

Of course, other options would provide a series of other complex experiences. The "right answer," in the case above, would be to have chosen both the performance measures and specifications, which in turn would have made other data-gathering opportunities available to the captain. As the captain made more decisions pertaining to data gathering, options such as "examine individual RDP component performance measures" would reveal themselves in the context of the captain's investigation, with subsequent scenarios and opportunities played out in video or animations, simulating the consequences of making those decisions as realistically as possible.[13]

Sidebar (fyi): In the true story on which the above example was based, the aggregated performance of the processors within the RDP left more than 50 percent idle capacity for the RDP considered as a whole. The government, however, asserted that each processor (AMP) was to have 50 percent idle capacity, not the RDP. The software runs on the AMPs, and there is no high-order language or compiler for the RDP. An investigation over the meaning of the word "processor" in the original specification ensued because of the government's assertion. In light of the government's actual specification, the aggregated performance measures used by the contractor were irrelevant.

The details of an interactive implementation of such a scenario are as varied as one can imagine, considering the many possible ways of utilizing video, audio, animation, and so on to create a poignant instructional experience for the student. Incorporating enabling skills and knowledge is a matter of specifying a mapping between the types of tasks assigned to the student and those enablers in the context of the multimedia interaction. In the simple example above, the student is presented with a scenario in which choices must be made about courses of action in investigating a situation in which risk has already become crisis. By being thrust into the situation, the student must necessarily "identify sources and types of risks...," "establish and apply a software acquisition and awareness process..." and so on. The precision and degree with which the course enablers are fulfilled depends upon the creativity and analysis of the combined team of content and multimedia developers.

A.2.3 Classroom Technology Decision Points

The landscape of educational decision making has changed with advances in instructional technology. If the ISD model (or other variation) is assumed as the basis for course development, then not only can we say that the decisions themselves have changed, but the timing as to when the decisions are made has also changed in reference to this model.

No longer must one ask whether instructional technology is usable in the classroom—it is. The question to ask is whether one *prefers* to use technology at all in the context of the curriculum, and if so, how? In terms of the instructional-design model in Figure A-1 on page 51, this means

13. Special thanks to Joe Besselman and Colonel Thomas Miller for providing the substance of this example from real life.

that it is now possible to ask whether or not to use instructional technology at the same time that instructional goals are considered, as opposed to waiting until we reach *Develop Instructional Strategy* or *Develop and Select Instructional Materials*. This is a big change over past practice, in which the use of instructional technology would have been considered only well after the objectives of the course were determined.

A Common Instructional Systems Design Process Model

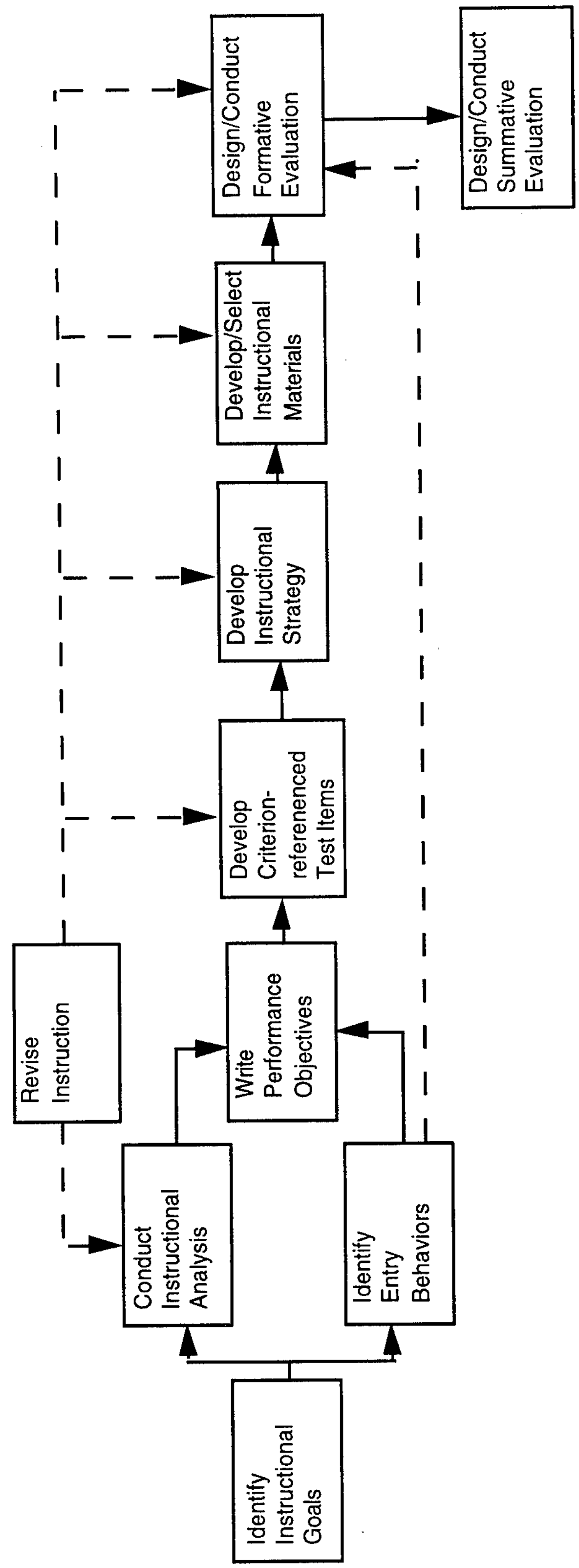

Figure 6: A Common Instructional Systems Design Process Model

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References

[ATP 85] Advanced Technology Program, Air Training Command, U.S. Air Force. *Non-personal Studies and Analysis Services for Assessment of New Training Technologies* (final technical report). June 1985.

[Anderson 85] Anderson, J.R., & Reiser, B.J. "The LISP Tutor," *Byte 10*, 4 (April 1985), pp. 8–14.

[Bloom 56] Bloom, Benjamin, S. & Krathwohl, David R. *Taxonomy of Educational Objectives: Handbook 1: Cognitive Domain*. Longman, 10 Bank St., White Plains, NY 10606,1956.

[Christel 94] Christel, M.G. "The Role of Visual Fidelity in Computer-Based Instruction," *Human-Computer Interaction 9* (1994), Lawrence Erlbaum Associates, Inc.: 183-223.

[Dick 85] Dick, Walter & Carey, Lou. The Systematic Design of Instruction.Glenview, Ill.: Scott, Foresman and Company, 1985.

[DTIC 88] Defense Technical Information Center. *Implementing Embedded Training (ET)* (AD-A201 401), vol(s). 1-10. Manned Systems Group, U.S. Army Research Institute for the Behavioral and Social Sciences, 1988-93.

[Fletcher 90] Fletcher, J.D. *Effectiveness and Cost of Interactive Videodisc Instruction in Defense Training and Education* (ADA 228 387). Defense Technical Information Center (DTIC).

[IBM 95] IBM (Redgate Communications, Corp.), *Multimedia Today 3*, 1 (January-March 1995).

[Laurel 86] Laurel, B. K. "Interface as Mimesis," 67-86. Norman, D.A. & Draper, S.W., eds. *User Centered System Design*. Hillsdale, NJ: Lawrence Erlbaum Associates, Inc., 1986.

[Mager 62] Mager, R.F. *Preparing Instructional Objectives*. Belmont CA: Fearon, 1962.

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This report provides a wide view of the costs, risks, and benefits associated with instructional technology alternatives. The number and variety of possible paths to learning through this technology have increased markedly in recent years with the advent of interactive multimedia, satellite communications, and the Internet. More than ever before, learning technologies have created new educational possibilities for people and organizations. In this era of increasing financial stringency, we are obligated to examine these new possibilities in light of their obvious advantages: replication of high-quality instruction, lower overall costs, increased quality in educational outcomes, and the ability to

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provide these benefits over long distances. This report will show that with today's computer-based instructional technology, the question is no longer *whether* to use the technology, but rather *how* to use it.